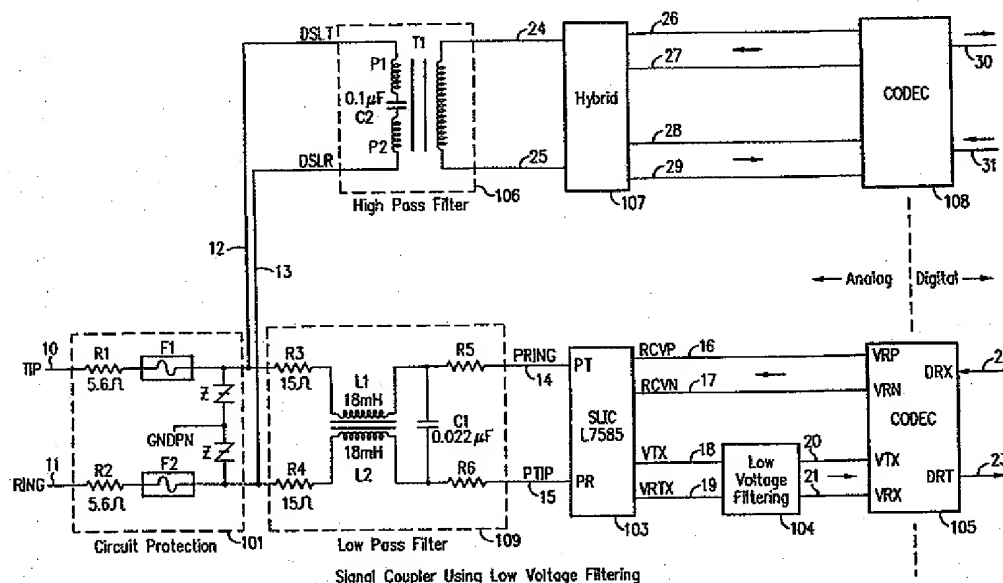




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**(54) Title:** SIGNAL COUPLER USING LOW VOLTAGE FILTERING**(57) Abstract**

A signal coupler is provided which decreases the number of discrete elements required to provide low pass filtering for the plain old telephone service (POTS). The low pass filtering is shifted to areas of the signal coupler circuit which do not operate with the high battery voltage present on telephone lines. The low voltage filtering reduces the need for components which are capable of operating in the high voltage environment and therefore reduces the space on the circuit board which is occupied by each of the signal couplers. In this way, the number of individual subscriber lines that a given circuit board can accommodate can be increased.

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SIGNAL COUPLER USING LOW VOLTAGE FILTERING

5

BACKGROUND1. FIELD OF THE INVENTION

10 The invention relates to a signal coupler for telephone lines containing both plain old telephone service (POTS) and digital signals where low voltage filtering is used in the POTS channel.

2. DESCRIPTION OF THE RELATED ART

15

Modern data networks commonly use complex digital signal processing (DSP) devices called modems to transport data over communication channels. Data is typically transported via an analog transmission signal which is representative of a synchronous, constant rate bit stream. This form of communication channel is suitable for the transmission of real-time information such as voice or video.

Often it is desirable to transmit both Plain Old Telephone Service (POTS) and digital data, either by Asymmetric Digital Subscriber Line (ADSL) or some other method, over the same line. The POTS frequency spectrum ranges from 300 to 3400 Hz. The ADSL frequency spectrum ranges from 24 kHz to 1100 kHz.

20 As shown in Figure 1, the data and POTS signals are transmitted over standard telephone lines 1 between a central office 2 and a subscriber's home 3. The subscriber 3 may have several modems 4a-4c and a POTS service 5. The subscriber 3 is typically connected to a central office 2 by twisted copper wire pair 1. At the central office 2, a signal coupler 6 is used to

filter, split and digitize signals coming into the central office 2 from a subscriber 3. The digital signals are processed through switching networks 7 and then sent through another signal coupler to another subscriber. Alternatively, the digital signal may be transmitted to another central office before being sent through another signal coupler to another subscriber. The signal coupler 6 converts the digital signals from the switching circuits 7 into analog signals for transmission to the subscriber as well as converting the analog input from the subscriber into digital signals which are sent to the switching circuits.

The transmission lines 1 between the central office and the subscriber may be twisted copper pairs, as shown in Figure 1. Other possibilities for transmission lines 1 include fiber optics. In any case, the equipment at the central office and at the subscriber must be protected against power cross, lightning strikes, or other high voltage events and current surges on the telephone line. The main voltage protection is accomplished outside of the central office. However, secondary voltage protection is usually included in the signal coupler. In Figure 2, the signal from the subscriber appears on the TIP and RING lines and the secondary voltage protection is shown as the circuit protection 101.

After the voltage and current protection is accomplished, the signal is split into data and voice lines. The data is sent at frequencies in the 20-30 kilohertz range and up while POTS voice information is nominally below 3000 Hz. The splitting, then, is normally done by using a high-pass filter for the data lines and a series of low-pass filters for the POTS lines. The series of filters is further required to remove the noise from the incoming telephone cable. Figure 2 shows the typical filtering circuit for the

POTS. In Figure 2, the voice filtering is accomplished by a multistage filtering circuit. The typical low pass filter used in the multistage filtering circuit has two to four stages of filtering.

5       The POTS signal from the subscriber, after passing through the protection circuit 101, is filtered by the multistage low pass filter 102. The multiple stages allow for filtering of multiple orders (i.e., a first order filter has only one stage while a second order  
10   filter has two stages). The components of each stage include an inductor pair and a capacitor. Stage 1 in Figure 2, for example, has inductor L1 connected in series with the TIP line after protection circuit 101 and inductor L1' connected in series with the RING line  
15   after the protection circuit. Capacitor C1 is connected across the TIP and RING lines after the inductor pair L1 and L1'. The remaining stages have similar components. In addition, the low pass filter 102 includes resistors R1 and R2 connected in series  
20   with the TIP and RING lines before they are connected to Stage 1 and resistors R3 and R4 connected in series with the TIP and RING lines after they exit stage N. In addition, the low pass filtering circuit may include  
25   an additional inductor pair acting as a common mode choke which rejects signals common to both input lines. The common mode choke is connected before stage 1 and is connected similar to inductor pair L1 and L1'.

Each component of the filtering circuit (i.e., the resistors, inductors, and capacitors) must be capable  
30   of withstanding the high battery voltage (48 V) and high DC currents (typically 25 mA) used in the subscriber loop. This necessitates that each of the components in the filtering circuit be discrete components which require a large amount of space on the  
35   circuit board. This space requirement restricts the number of lines that can be placed on a given circuit

board. It is desirable, then, to reduce the amount of filtering which must be accomplished in the high voltage mode.

5

# SUMMARY OF THE INVENTION

Accordingly, the present invention provides a signal coupler circuit which provides the circuit protection and the filtering in a way that allows conservation of space on the circuit board at the central office. This is done by filtering the voice lines, at least in part, in a portion of the circuit where the high battery voltage is no longer present.

An analog signal capable of containing both POTS and data signals is present between the TIP and RING lines. The TIP and RING lines are the components of a standard twisted pair configuration of telephone service. The invention, however, is not restricted to twisted pairs and is useful for any transmission method of telephone service.

The signal between TIP and RING is first inputted to a voltage surge protection circuit. The surge protection circuit limits voltage spikes and current surges which could damage other components. The main voltage and current surge protection is connected to the transmission line outside of the central office so that the protection required on the circuit board inside the central office is secondary circuit protection.

The output signal from the protection circuit is inputted to a low-pass filter. The low-pass filter occupies a minimal amount of space while being capable of accommodating the high voltage telephone lines. In the preferred embodiment, only one stage of filtering is used. More stages of filtering could be used at this point but, because of the high battery voltage,

these stages utilize a great deal of circuit board space.

The output signal from the low-pass filter is then sent to a standard subscriber loop interface circuit (SLIC) device. The SLIC is a standard chip which splits the two incoming lines into four lines, a pair of receive lines and a pair of transmit lines.

The transmit lines are finally filtered after the SLIC chip to remove the remainder of the noise. When the filtering is done after the signal is passed through the SLIC component, the high battery voltage is no longer present. The filtering components, then, can exist on a single chip and will take up much less space on the circuit board. Alternatively, some of the filtering may be accomplished digitally after the signal has been digitized by the CODEC.

The present invention provides a way of dispensing with the multistage high-voltage filtering which typically occurs before the SLIC in favor of low voltage, and therefore smaller and more compact, filtering on the transmit lines after the SLIC. The resulting savings in space will allow more signal couplers to exist on a given circuit board.

25

#### DESCRIPTION OF THE FIGURES

Figure 1 illustrates a block diagram of a telephone subscriber loop.

Figure 2 illustrates a circuit diagram of a prior art POTS filtering arrangement.

Figure 3 is a block diagram of a device to accomplish the present invention for POTS filtering.

Figure 4 is a circuit diagram of the preferred embodiment of the present invention of POTS filtering.

Figure 5 shows a second embodiment where part of the low voltage filtering is accomplished on the digital side of the circuit.

5

#### DESCRIPTION OF THE INVENTION

In accordance with the present invention, most of the POTS filtering is removed from areas of the circuit which require components capable of handling the high battery voltage and DC current of the telephone subscriber loop to areas of the circuit where only low voltage filtering is required.

Figure 3 shows a block diagram of the signal coupler 100 which will accomplish this result. The TIP line 10 and RING line 11 represent the two wires of the twisted copper pair. TIP line 10 and RING line 11 are inputted to the protection circuit 101. The protection circuit 101, a standard well-known circuit, provides the voltage and current protection necessary to guard the remainder of the device from high voltage and high current surges typically caused by lightning strikes, power cross, or other unexpected electrical events. The Bellcore administrative standard LATA Switching System Generic Requirements (LSSGR), the standard adopted by all Bell operating companies, has a first level lightning strike test and a second level lightning strike test. (See Lucent Technologies, *Overvoltage Protection of Solid-State Subscriber Loop Circuits*, APPLICATION NOTE, FEB. 1997, at 9-10). In the first level test, the circuit must survive the tests outlined in Table 1. The circuit need not survive the second level test, but no electrical shock or fire hazards can be created.



Table 1  
Bellcore First Level Lightning Strike Test

$V_p$ (V)	Pulse ( $\mu$ s) (Rise Time/Decay Time)	$I_{peak}$ (A)	Reps
$\pm 600$	10/1000	100	50
$\pm 1000$	10/360	100	50
$\pm 100$	10/1000	100	50
$\pm 2500$	2/10	500	50

5

In a typical subscriber loop, the battery voltage across TIP 10 and RING 11 is 48V and the loop may typically carry a current of from 23-35 mA. Although the current is nominally 25 mA, it could range as high as 120 mA.

The output signal from the protection circuit 101 on lines 12 and 13 is sent to low pass filter 109. It's a good practice to use different numbers for components that are different (particularly when one is prior art and one is part of the invention). In addition, the lines DSLT 12 and DSLR 13 are inputted to high pass filter 106. Low pass filter 109 passes the POTS signal while not passing the data signal. High pass filter 106 does not pass the POTS signal while passing the data signal. In this way, the data path is separated from the POTS path.

In addition to splitting the POTS signal and the data signal, low pass filter 109 also provides enough filtering to prevent overloading of the subscriber loop interface circuit (SLIC) 103. This requires that the low pass filter 109 have at least one stage. In the preferred embodiment, low pass filter 109 has only one stage of filtering. The output of low pass filter 109

is PTIP 14 and PRING 15. Signals PTIP 14 and PRING 15 are inputted to SLIC 103.

The subscriber loop interface circuit (SLIC) 103 is a standard integrated circuit which includes the function of splitting two lines which carry both transmit and receive signals (i.e., bi-directional transmission) into four lines, two of which carry the transmit signal and two of which carry the receive signal. The SLIC 103 must also handle the 48 volt battery voltage supplied by the central office and 25 mA of current or more, as opposed to the typically 5 V commonly handled by such circuits. SLIC chips are standard chips and may be purchased, for example, from Lucent Technologies, AMD, Harris, or Mitel. The Lucent Technologies chip L7585 is the preferred component used with this invention. With the use of the standard SLIC chip, the filtering circuit shown in Figure 3 will appear identical to a standard prior art filtering circuit for compatibility with existing equipment.

The SLIC 103 outputs the transmitted signals on lines 18 and 19. The received signals are on lines 16 and 17. The received signals are those signals received from the central office for transmission through the signal coupler 100, to the subscriber. Lines TIP 10 and RING 11 will carry both the transmit and the received signals, the transmit signals being those that are received into the coupling circuit 100 and the receive signals being those that are received out of the coupling circuit 100.

The transmit signals, on lines VTX 18 and VRTX 19, are inputted to a low voltage filter 104. Filter 104 finishes filtering the incoming transmit signals. The receive signals, RCVP 16 and RCVN 17, are not filtered in this circuit. These signals would be filtered in another circuit as transmit signals before being switched into the circuit illustrated here as receive

signals. The other coupling circuits and the switching circuits are shown in Figure 1.

The four lines -- RCVP 16, RCVN 17, VTX 20 and VRTX 21 -- are connected to coder/decoder circuit (CODEC) 105. CODEC 105 receives the digital signal DRX 22 and outputs the analog receive signal between lines 16 and 17. CODEC 105 receives the filtered analog transmit signal between lines 20 and 21 and outputs the corresponding digital signal on DRT 23. CODEC 104 may also receive a clock signal 24 and a framing signal 25 in order to coordinate with a digital processing and switching circuit at the central office.

The high pass filter 106, in addition to filtering out the POTS signal, also filters the 48 V battery voltage from between lines DSLT 12 and DSLR 13. The output lines of high pass filter 106, lines 24 and 25, are connected to Hybrid 107. Hybrid 107 performs the same two-wire to four-wire function that SLIC 103 performs without the necessity of being capable of handling the high battery voltage or the associated high DC current. The Hybrid may need to operate with high current in higher frequency ranges. The four-wire side of Hybrid 107 includes receive signals on receive lines 26 and 27 and transmit signals on lines 28 and 29. The four-wires 26, 27, 28 and 29 are connected to CODEC 108. Codec 108 converts the analog transmit signals received on lines 28 and 29 to digital signals output on line 31 and the digital receive signals received on line 30 to analog signals output on lines 26 and 27. The digital lines 30 and 31 are connected to the digital processing and switching circuits at the central office (See Figure 1).

Figure 4 illustrates signal coupler 100 showing in greater detail the circuitry within the circuit protection circuit 101, the low pass filter 109 and the high pass filter 106.

The circuit protection 101 in Figure 4 has two components, current protection and voltage protection. The current protection on TIP line 10 is accomplished by resistor R1 in series with fuse F1. On RING line 5 11, the current protection is accomplished by resistor R2 in series with fuse F2. The combinations of resistor and fuse adhere to the Bellcore specifications, fuses F1 and F2 opening only in second level testing. In the embodiment shown in Figure 4, R1 10 and R2 are both 5.6  $\Omega$  resistors.

The voltage protection is provided by component Z, which acts as a triggered voltage shunt. Monolithic protection devices consisting of one or more SCR-type thyristers are commonly available under the trade names 15 such as SURGECTAR (Harris, Inc.), SIDACTOR (Teccor, Inc.) and LB1201 SLIC Protector (Lucent Technologies, Inc.). Although any device which prevents the voltage between lines TIP 10 and RING 11 from exceeding the Bellcore standard could be used, devices such as the 20 SIDACTOR have the advantage of being benign until they are triggered. Preferably, Z is a SIDACTOR. Component Z is connected across lines TIP 10 and RING 11 with an output leg attached to a protection ground GNDPN. After Z triggers, it shunts the voltage across it directly to 25 GNDPN. Preferably, Z should be chosen so that it triggers at around 200 volts.

The low pass filter 109 in Figure 4 is a single-stage LRC circuit. Line 12 is connected in series with resistor R3, inductor L1, and resistor R5. Line 13 is 30 connected in series with resistor R4, inductor L2 and resistor R6. Capacitor C1 is connected across the two lines, from a point between inductor L1 and resistor R5 to a point between inductor L2 and resistor R6. Inductors L1 and L2 comprise a four terminal inductor 35 with an iron core. In Figure 4, R3 and R4 are 15  $\Omega$

resistors, R5 and R6 are 20  $\Omega$  resistors, L1 and L2 are 18 mH inductors and C1 is a 0.022  $\mu$ F capacitor.

Although the low pass filter illustrated in Figure 4 is the preferred embodiment, other embodiments will be apparent to one skilled in the art. For example, providing an initial coupled inductor as a common mode choke, adding further stages of filtering or using different combinations of resistors, capacitor and inductor in the filtering are options. The components of the low pass filter, however, operate with the 48 volt battery voltage provided at the central office and the inductors have to pass tens of milliamperes of current without saturation. As such, the components require a large amount of circuit board space.

The high pass filter 106 in Figure 4 includes capacitor C2 and transformer T1. Transformer T1 has a first side and a second side. The first side is split and a first coil P1 and a second coil P2 of the first side are coupled through capacitor C2. An input lead of the first coil P1 is connected to line DSLT 12 and the opposite input lead of the first coil P1 is connected to a lead of capacitor C2. The opposite lead of capacitor C2 is connected to an input lead of the second coil P2. The opposite input lead of coil P2 is connected to line DSLR 13. The two leads of the second coil of transformer T1 are connected to Hybrid 107.

The high pass filter 106 illustrated in Figure 4 is of a standard type, any circuit which separates the high frequency data input from the DC and POTS signals can be used. After this separation is accomplished, the Hybrid 107 need only operate at low voltage.

The low voltage filter 104 can be any continuous time filter which provides the desired filtering. Several of these filters are well known in the art. Among the well known integrated circuit continuous time filters are  $G_m$ -C filters and MOSFET-C filters. Each of

these filter types can be implemented with multiple stages providing for filters of several orders. A standard ladder filter (which employs inductors and capacitors for a multistage filtering circuit similar to the high voltage filter shown in Figure 2) will accomplish the low voltage filtering, however it is difficult to accurately construct an inductor on an IC chip and implementation with individual components will take a great deal of space on the circuit board and defeat the purpose of the invention.

A second embodiment of the invention is shown in Figure 5. The embodiment shown in Figure 5 differs from the preferred embodiment shown in Figure 4 in that part of the filtering is shifted to the digital side of CODEC 105. In this embodiment, the filtering is split between a Low Voltage Filter 110 and a Digital Filtering Circuit 111 located on line 23.

The examples illustrated here are representative examples and in no way limit the scope of this application. Other obvious embodiments of the invention will be apparent to one skilled in the art and are included within the scope of this application. One obvious embodiment is to not have a data path so that only POTS signals are processed.

25

CLAIMS

We claim:

- 5 1. A signal coupler, comprising:  
a circuit protection having a line side and a  
circuit side, the line side being coupled to  
a TIP line and a Ring line;  
a low pass filter having a first pair of leads and  
10 a second pair of leads, the first pair of  
leads being coupled to the circuit side of  
the circuit protection;  
a subscriber loop interface circuit having a third  
pair of leads, a transmit pair of leads and a  
15 receive pair of leads the third pair of leads  
being connected to the second pair of leads  
of the low pass filter;  
a low voltage filter having an input pair of leads  
and an output pair of leads, the input pair  
20 of leads being connected to the transmit pair  
of leads of the subscriber loop interface  
circuit; and  
a coding/decoding circuit having a digital  
transmit lead, a digital receive lead, a pair  
25 of analog transmit leads, and a pair of  
analog receive leads, the pair of analog  
transmit leads being connected to the output  
of the low voltage filter and the pair of  
analog receive leads being connected to the  
30 receive pair of leads of the subscriber loop  
interface circuit.
2. A signal coupler as in Claim 1 and further  
comprising:  
35 a high pass filter having a fourth pair of leads  
and a fifth pair of leads, the fourth pair of

leads being coupled to the circuit side of the circuit protection;

5 a Hybrid having a sixth pair of leads, a transmit pair of leads, and a receive pair of leads, the sixth pair of leads being connected to the fifth pair of leads of the high pass filter; and

10 a data coding/decoding circuit having an analog transmit pair of leads, an analog receive pair of leads, a digital transmit lead, and a digital receive lead, the analog transmit pair of leads being connected to the transmit pair of leads of the Hybrid and the analog receive pair of leads being connected to the  
15 receive pair of leads of the hybrid.

3. A signal coupler as in Claim 1, wherein the line side of the circuit protection has a first line lead and a second line lead, the circuit side of  
20 the circuit protection has a first circuit lead and a second circuit lead, and the circuit protection comprises:

a first resistor having a first lead and a second lead, the first lead of the first resistor  
25 being the first line lead;

a first fuse having a first lead and a second lead, the first lead of the first fuse being coupled to the second lead of the first resistor, the second lead of the first fuse providing the first circuit lead;  
30

a second resistor having a first lead and a second lead, the first lead of the second resistor being the second line lead;

a second fuse having a first lead and a second lead, the first lead of the second fuse being  
35 coupled to the second lead of the second



resistor, the second lead of the second fuse providing the second circuit lead; and a triggered voltage shunt having a first lead and a second lead, the first lead of the  
5 triggered voltage shunt being connected between the first circuit lead and the second lead of the triggered voltage shunt being connected to the second circuit lead.

10 4. A signal coupler as in Claim 3, wherein the triggered voltage shunt is a monolithic protection device comprising at least one thyristor, the monolithic protection device also having an output  
15 lead, and the output lead being connected to a ground protect, the monolithic protection device operating to shunt a voltage between the first lead of the triggered voltage shunt and the second lead of the triggered voltage shunt through the  
20 output lead of the triggered voltage shunt to the ground protect if the voltage reaches a trigger level.

5. A signal coupler as in Claim 4, wherein the trigger level is inclusively between 200 and 250 volts.

25

6. A signal coupler as in Claim 1, wherein the first pair of leads of the low pass filter includes a first tip lead and a first ring lead, the second pair of leads of the low pass filter includes a  
30 second tip lead and a second ring lead, and the low pass filter comprises a one stage filter including:

35 a first resistor having a first lead and a second lead, the first lead of the first resistor being the first tip lead of the circuit protection;

- a first inductor having a first lead and a second lead, the first lead of the first inductor being coupled to the second lead of the first resistor;
- 5 a second resistor having a first lead and a second lead, the first lead of the second resistor being coupled to the second lead of the first inductor, the second lead of the second resistor being a the second tip lead;
- 10 a third resistor having a first lead and a second lead, the first lead of the third resistor being the first ring lead of the circuit protection;
- a second inductor having a first lead and a second lead, the first lead of the second inductor being coupled to the second lead of the third resistor;
- 15 a fourth resistor having a first lead and a second lead, the first lead of the fourth resistor being coupled to the second lead of the second inductor, the second lead of the fourth resistor being the second ring lead of the low pass filter; and
- 20 a capacitor having a first lead and a second lead, the first lead of the capacitor being connected to the second lead of the first inductor, the second lead of the capacitor being connected to the second lead of the second inductor.
- 25
- 30
7. A signal coupler as in Claim 6, wherein the low pass filter further includes a common mode choke connected to the first pair of leads of the low pass filter.
- 35

8. A signal coupler as in Claim 2, wherein the high pass filter comprises:

a first capacitor having a first lead and a second lead;

5 a second capacitor having a first lead and a second lead, the first lead of the second capacitor and the first lead of the first capacitor providing the fourth pair of leads of the high pass filter; and

10 a transformer having a primary and a secondary, the primary having a first lead and a second lead and the secondary having a third lead and a fourth lead, the first lead of the primary being connected to the second lead of the first capacitor, the second lead of the primary being connected to the second lead of the second capacitor, the third lead of the secondary and the fourth lead of the secondary providing the fifth pair of leads  
15 of the high pass filter.  
20

9. A signal coupler as in Claims 2, wherein the high pass filter comprises:

a transformer having a first coil, a second coil,

25 and a third coil, the first coil having a first lead and a second lead, the second coil having a first lead and a second lead, and the third coil having a first lead and a second lead, the first lead of the first coil and the second lead of the second coil  
30 providing the fourth pair of leads of the high pass filter, the first lead of the third coil and the second lead of the third coil providing the fifth pair of leads of the high  
35 pass filter; and

- a capacitor having a first lead and a second lead,  
the first lead of the capacitor being  
connected to the second lead of the first  
coil of the transformer, the second lead of  
the capacitor being connected to the first  
lead of the second coil of the transformer.
10. A signal coupler as in Claims 1, wherein the low  
voltage filter comprises a  $G_m$ -C filter having at  
least one order of filtering.
11. A signal coupler as in Claim 10, wherein the  $G_m$ -C  
filter includes a first order filter.
12. A signal coupler as in Claim 10, wherein the  $G_m$ -C  
filter includes a second order filter.
13. A signal coupler as in Claim 10, wherein the  $G_m$ -C  
filter includes more than two orders of filtering.
14. A signal coupler as in Claim 1, wherein the low  
voltage filter comprises a MOSFET-C filter having  
at least one order of filtering.
15. A signal coupler as in Claim 14, wherein the  
MOSFET-C filter includes a first order filter.
16. A signal coupler as in Claim 14, wherein the  
MOSFET-C filter includes a second order filter.
17. A signal coupler as in Claim 14, wherein the  
MOSFET-C filter includes more than two orders of  
filtering.
18. A signal coupler as in Claim 1 and further  
comprising a digital filter coupled to the digital  
side of the coding/decoding circuit.

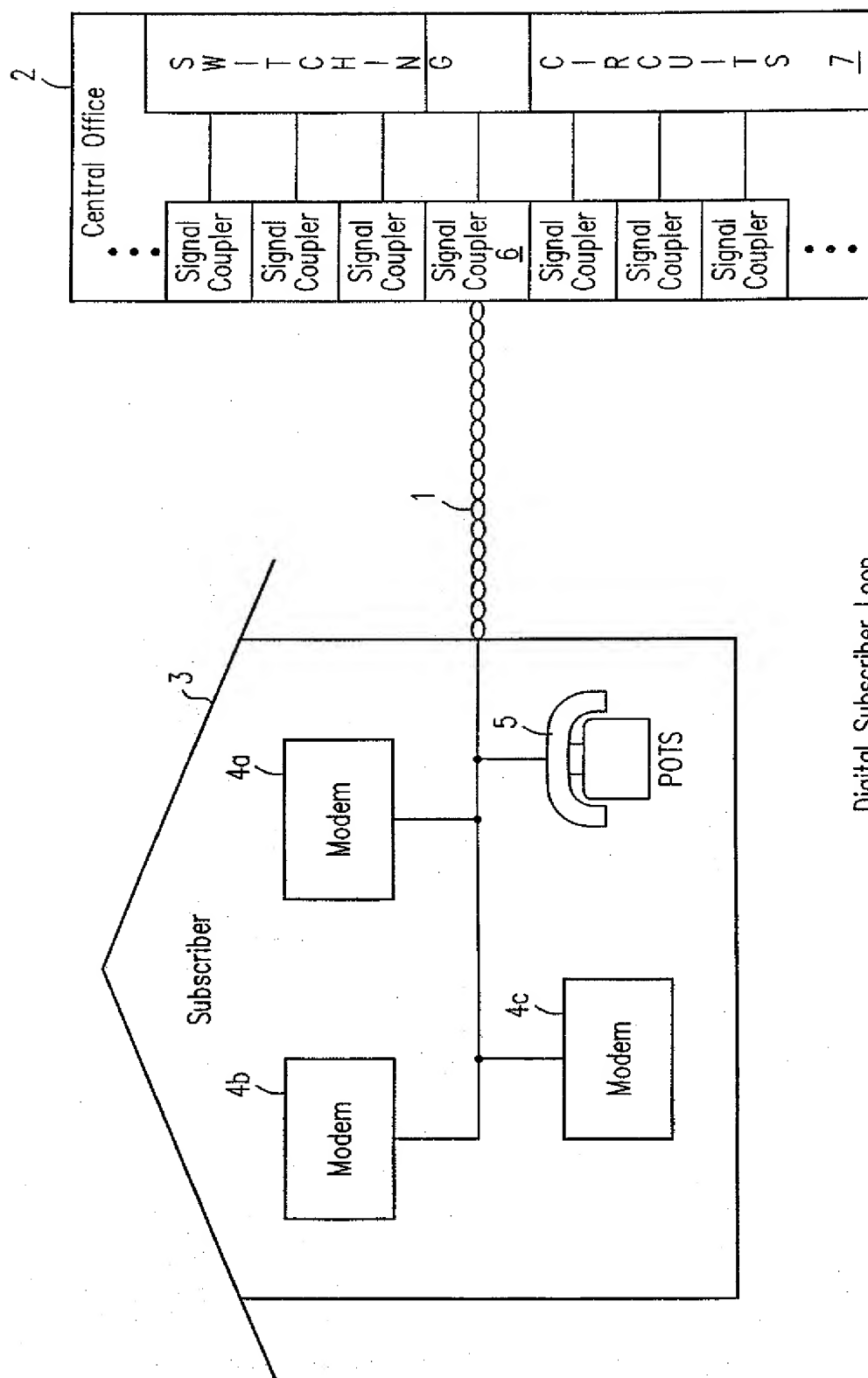
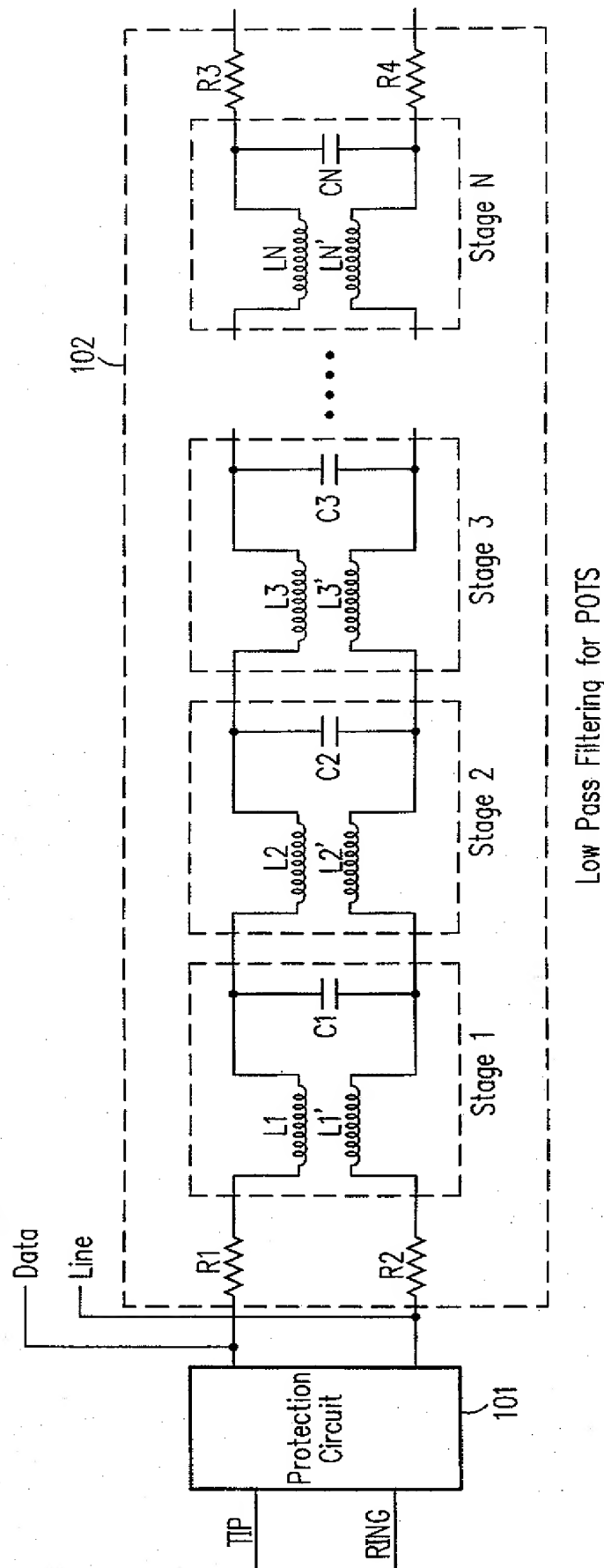
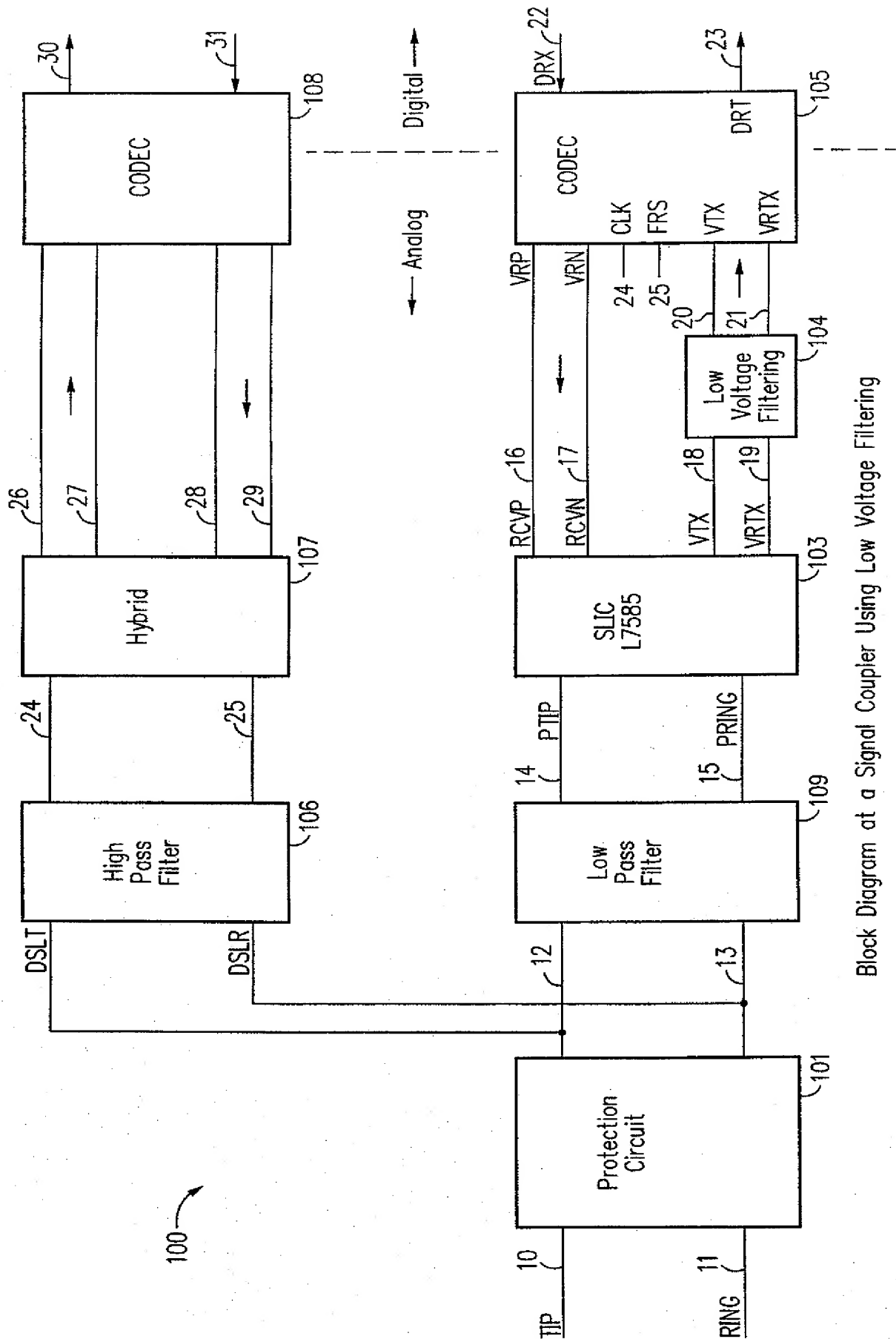


FIG. 1  
(PRIOR ART)

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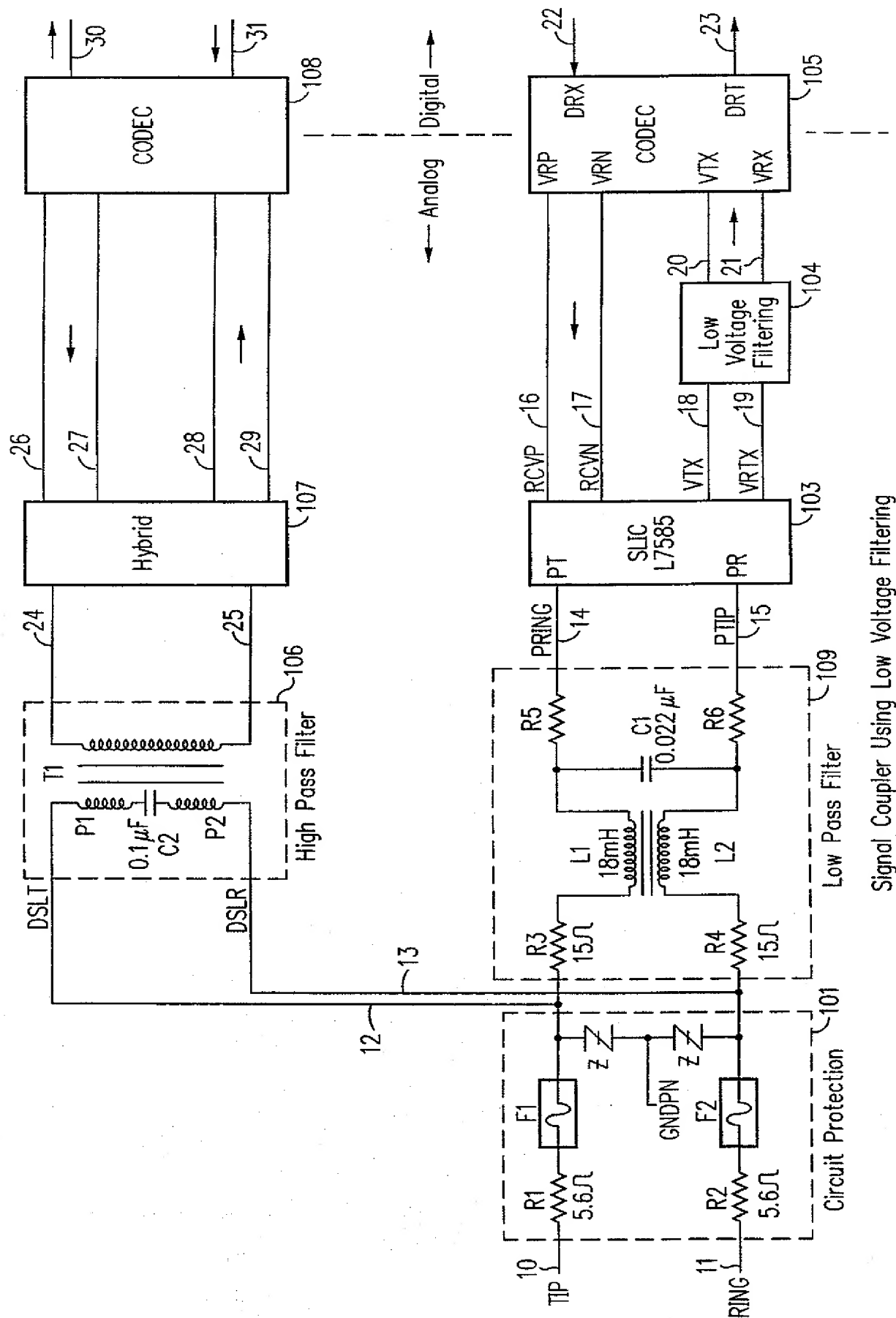
FIG. 2  
(PRIOR ART)

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Block Diagram of a Signal Coupler Using Low Voltage Filtering

FIG. 3



## Signal Coupler Using Low Voltage Filtering

FIG. 4



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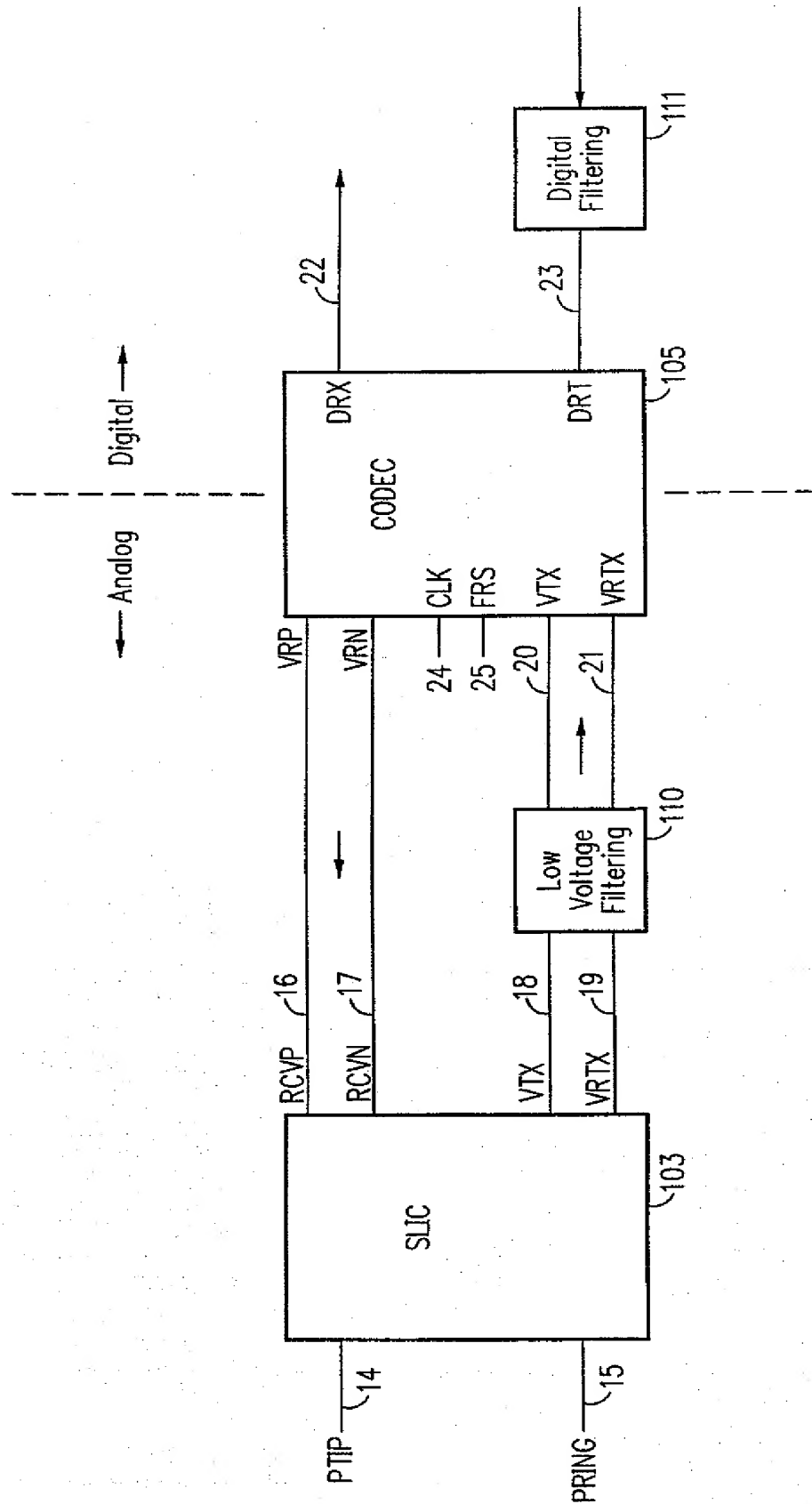


FIG. 5

# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 99/07636

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H04L27/00 H04L25/08 H04M3/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04L H04M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 677 938 A (BELL TELEPHONE MFG) 18 October 1995 (1995-10-18) column 2, line 15-31 column 3, line 8-27 column 3, line 43 - column 4, line 14 figure 1	1,2,6, 8-10,13
A	US 4 903 295 A (SHANNON WILLIAM ET AL) 20 February 1990 (1990-02-20) column 2, line 9-48 column 3, line 49 - column 4, line 51 figure 2	3-5
A	FR 2 719 721 A (SGS THOMSON MICROELECTRONICS) 10 November 1995 (1995-11-10) page 3, line 11 - page 4, line 22 figure 3	3-5

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

27 July 1999

Date of mailing of the international search report

04/08/1999

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 99/07636

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